Why Do Fluxes Near the Granular Bed Scale Differently Than Within the Transport Layer?

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November 23, 2022

Abstract

Some aspects of the dynamics of aeolian transport over a flat sediment bed have been thoroughly investigated and are relatively well understood. The interactions between grains in transport and the wind give rise to well-known dynamical scaling laws for the fluxes and concentrations of grains in most of the transport layer. However, recent work has revealed a sudden shift in these scaling laws near the granular surface and below. While the vertical flux of grains in the transport layer scale linearly with excess wind shear stress, the vertical flux near the granular surface—the 'erosion rate'—scales linearly with wind speed. Analysis of numerical modeling results reveal that near-surface horizontal and vertical fluxes are important for the instability that leads to wind ripple growth and stabilization as well as ripple propagation. A few main open questions are: What are the physical mechanisms behind the scaling of the erosion rate with wind speed? Could they arise from the small subpopulation of high-energy grains, who's characteristics scale differently than the average grain in transport? As these grains move downward from the free-wind layer, do they tend to retain their properties as they pass through the feedback layer, delivering their energy, momentum and scaling directly to the bed? Do collisions between grains near and within the bed, which redistribute energy and momentum from high-energy impacts, play a key role in determining the scaling of near-bed fluxes? How important are potential collective effects that can occur when impacts with sufficient energy to excite the bed occur close together in time and space? An answer to these questions would help complete our understanding of the physics of aeolian transport, with repercussions that shed light onto the emergence and propagation of wind ripples. Using a detailed grain scale numerical model, we are investigating the dynamics of grains near the granular bed, and what saltation properties drive these dynamics. Preliminary results, including velocity distributions near the bed, indicate that the signal from high-energy grains that traverse the feedback layer from above reaches the bed surface, consistent with the hypothesis that the surface erosion rate is related to this small population of grains who's characteristics scale with the free-wind speed.

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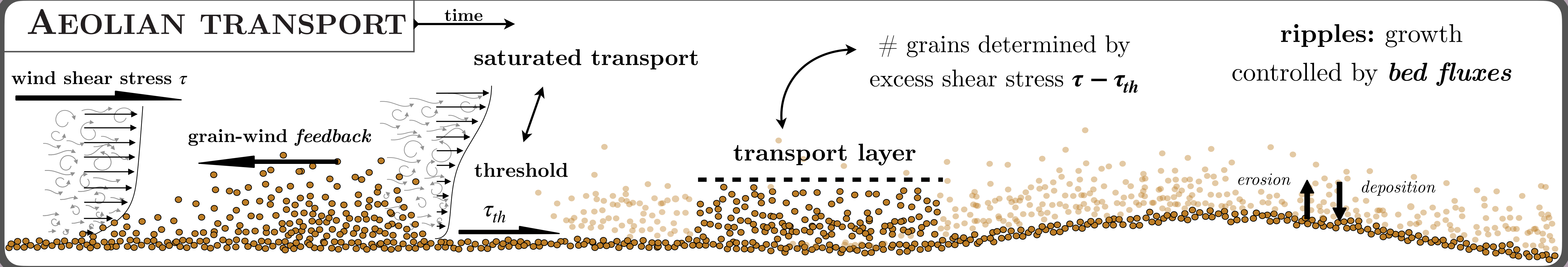
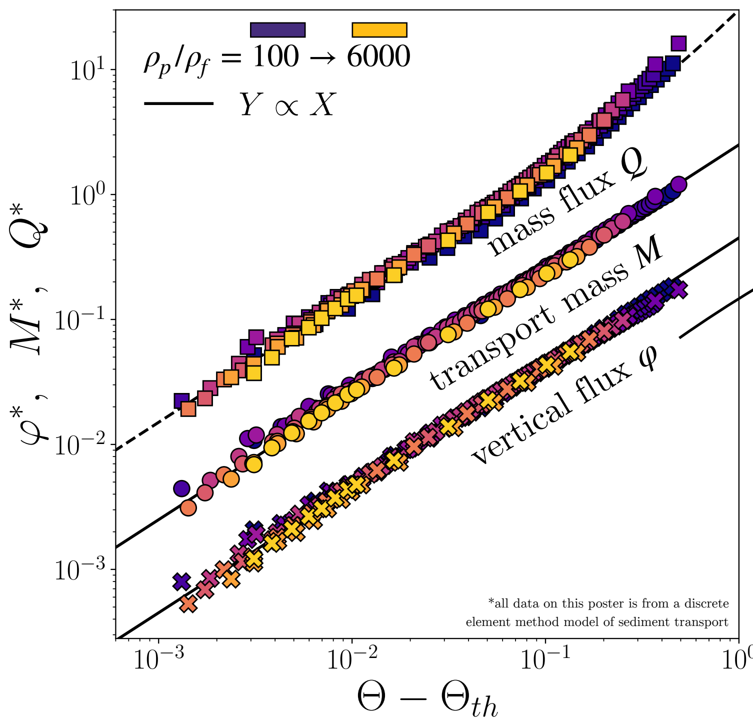
Aeolian transport



Shear stress scaling

Transport layer

grain fluxes scale with excess **shear stress** → **all particle quantities** (velocities, hop lengths/heights) ≈ **constant with wind speed.**



Focus: vertical flux

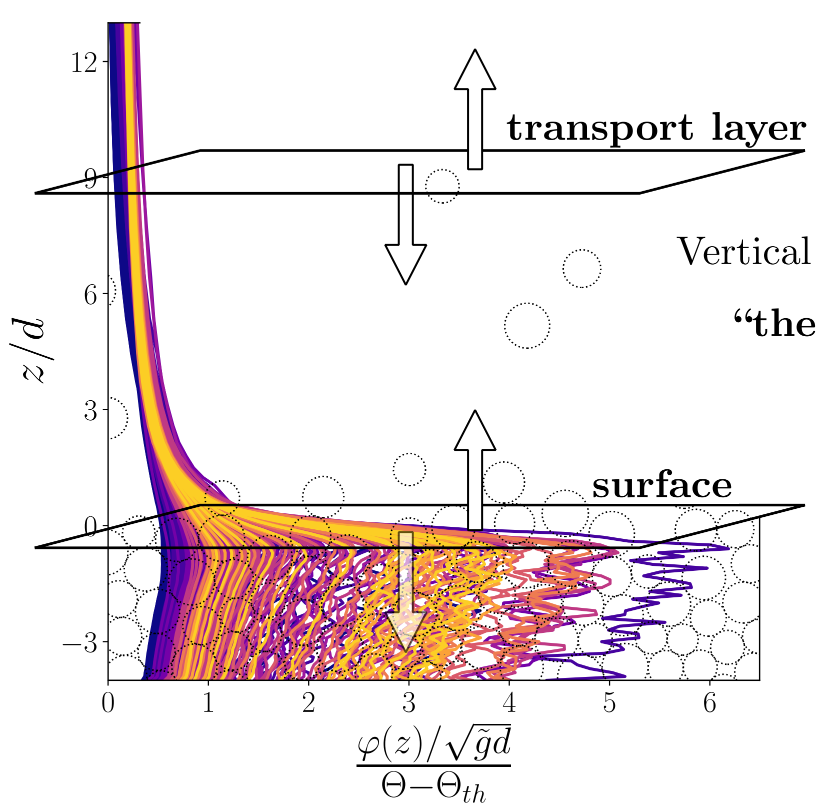
grains crossing plane vertically

= "**erosion**"/"deposition" at ***surface***

rescaled shear stress

$$\Theta = \frac{\rho_f u_*^2}{(\rho_p - \rho_f) g d}\ \left[\frac{\text{fluid shear stress}}{\text{grain pressure}}\right]$$

Erosion rate scaling discontinuity



Vertical flux *at the surface* φ_b ("b" for bed)

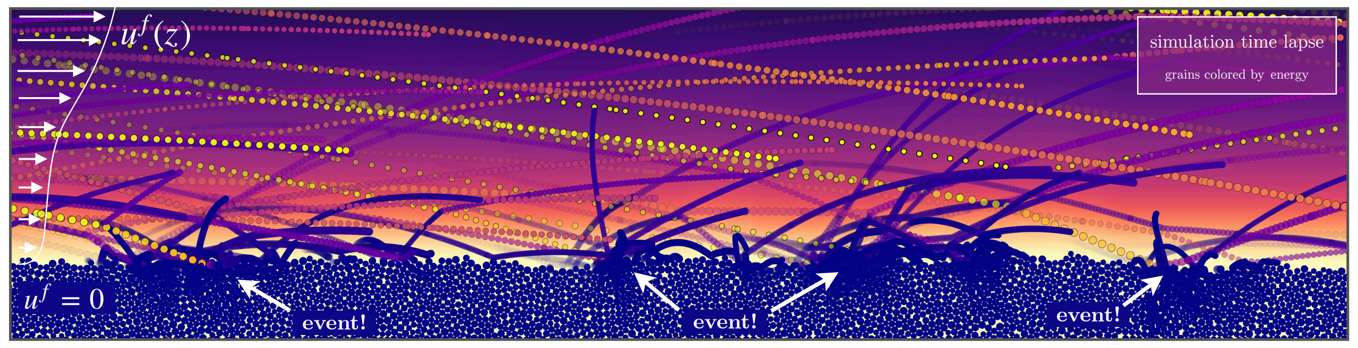
"the erosion rate" *suddenly* scales differently

† **Erosion rate** determines bed change & **ripple dynamics!**

Need to understand anomalous scaling!

How does **impact flux** *cause* **bed flux**?

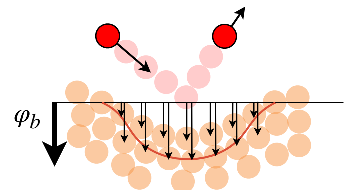
...seems like a reasonable question

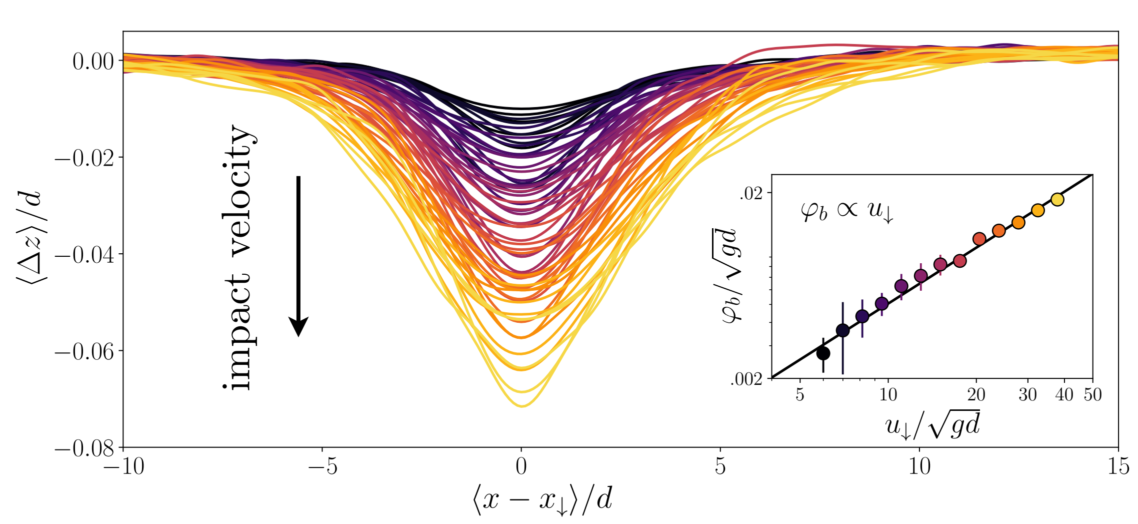


***observations* → rarefied bed events**

Analysis

→ vertical bed flux per impact





bed flux φ_b scales with impact velocity $u_\downarrow$ ...

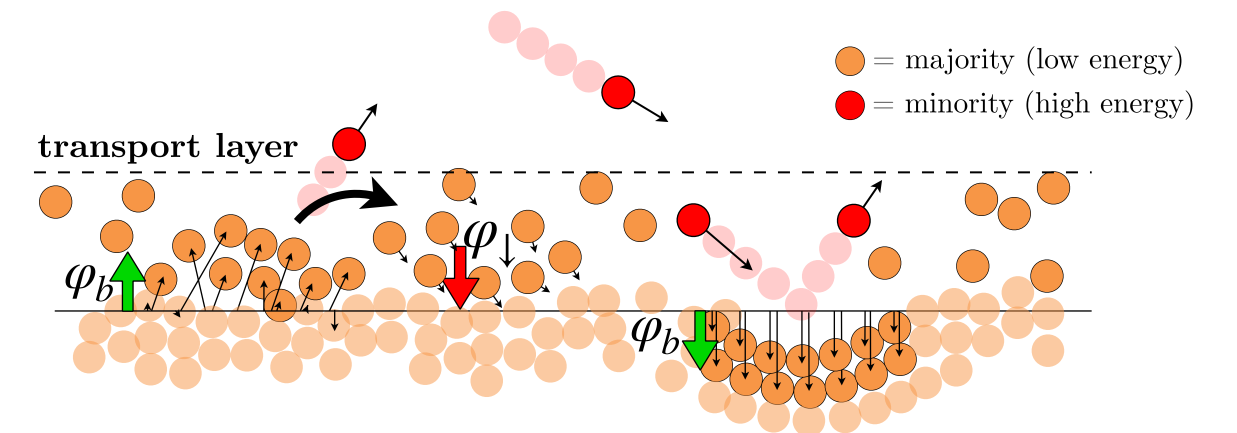
PARADOX:

$\sum_{\text{impacts}}$ over all impacts → $\varphi_\downarrow \langle u_\downarrow \rangle \ldots \langle u_\downarrow \rangle \approx$ constant!

bed flux *cant scale linearly with* **impact flux**

$$\varphi_b \nsim \varphi_\downarrow$$

Cause ⇆ Effect



actually... **bed flux** *causes* **impact flux**

New point of view

impact flux ⇒ *ejections*

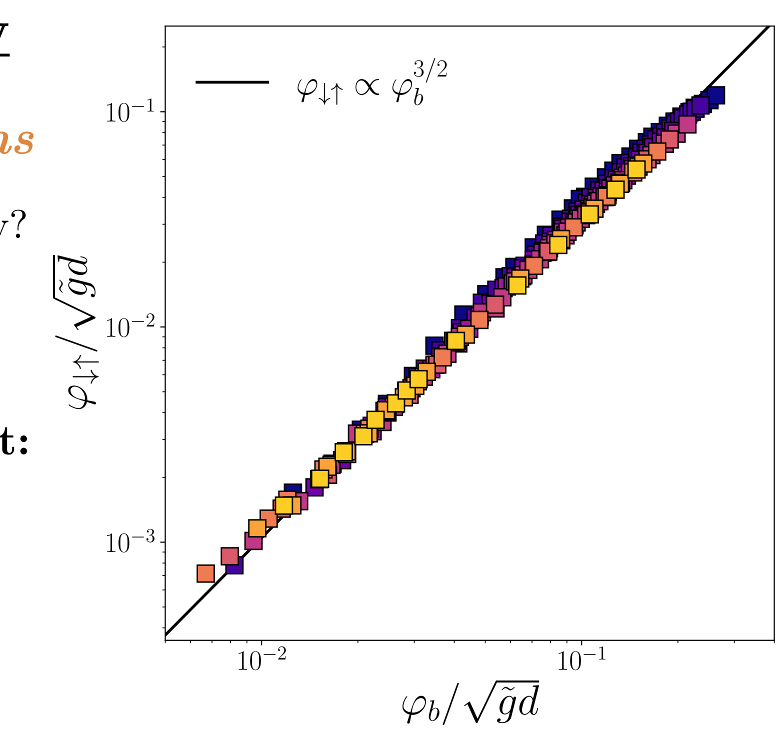
ejections ∝ potential energy?

↓

From impact event geometry, we *may* expect:

(data not shown)

$$\varphi_{\downarrow\uparrow} \sim \varphi_b^{3/2}$$



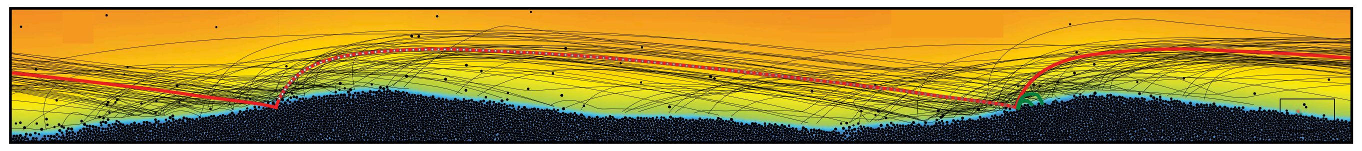
Next Steps

Further analyze bed flux dynamics

→ ***rare***, high energy **events** that ***drive bed flux***

→ **bed flux** dependence on **wind speed?**

Ripples → **bed flux** makes flat bed ***unstable***! Use this knowledge to further investigate *ripple emergence*/dynamics...



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